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Medium-frequency sky-wave broadcasting: effect of polarization on interference

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Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

MEDIUM-FREQUENCY SKY-WAVE BROADCASTING: EFFECT OF POLARIZATION ON INTERFERENCE

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(RA-55)

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MEDIUM-FREQUENCY SKY-WAVE BROADCASTING: EFFECT OF POLARIZATION ON INTERFERENCE

SUMMARY

Horizontal transmitting aerials may be used at medium frequencies for short-distance broadcasting via the ionosphere. The use of horizontal rather than vertical aerials affects the strength of interfering signals which propagate at night to greater distances. It is shown that less interference is caused in temperate latitudes when horizontal aerials are used, while in tropical latitudes the level of interference is unlikely to exceed that normally experienced in temperate latitudes.

1. INTRODUCTION

Horizontal transmitting aerials are sometimes used at medium frequencies (m.f.) for short-distance broadcasting via the ionosphere instead of vertical aerials, because they radiate more efficiently at high angles. The purpose of this report is to consider how the use of horizontal aerials affects the strength of signals which might cause interference at distances greater than 1000 km. The discussion is confined to sky-wave propagation, because ground-wave radiation from horizontal m.f. aerials is extremely small.

Two factors which influence the strength of a received sky wave are:

(1) the strength of the wave radiated towards the ionosphere by the transmitter

(2) the efficiency with which the wave incident upon the ionosphere excites the ordinary wave. The extraordinary wave can be disregarded at m.f. because it suffers much more absorption than the ordinary wave.

Both of these factors are modified if a horizontal transmitting aerial is used, and they are therefore discussed in greater detail in the sections which follow. The transmitting aerial has no further influence on the wave once it has entered the ionosphere, and no other factors need be considered.

2. EFFECTIVE RADIATED POWER

Vertical radiation patterns of typical vertical and horizontal m.f. transmitting aerials, situated on ground of average conductivity, are compared in Fig. 1. The distance from the aerial is assumed to be large enough for the ground wave to be disregarded, but an allowance has been made for the diffraction of low-angle sky waves around the surface of the Earth. Both aerials are assumed to radiate the same power.

The vertical aerial is a $0{\cdot}5\lambda$ mast radiator and the horizontal aerial is a $0{\cdot}5\lambda$ dipole raised $0{\cdot}4\lambda$ above the ground. It is worth noting that the horizontal aerial does not radiate horizontal polarization in all directions; in the plane containing the dipole the plane of polarization is in fact vertical. In general, the radiation from a horizontal aerial is elliptically polarized, although the horizontal component predominates over a wide range of angles. At low angles of elevation, the horizontal component radiated by the aerial described here exceeds the vertical component by 10 dB or more, over 120° arcs centred on the plane perpendicular to the dipole.

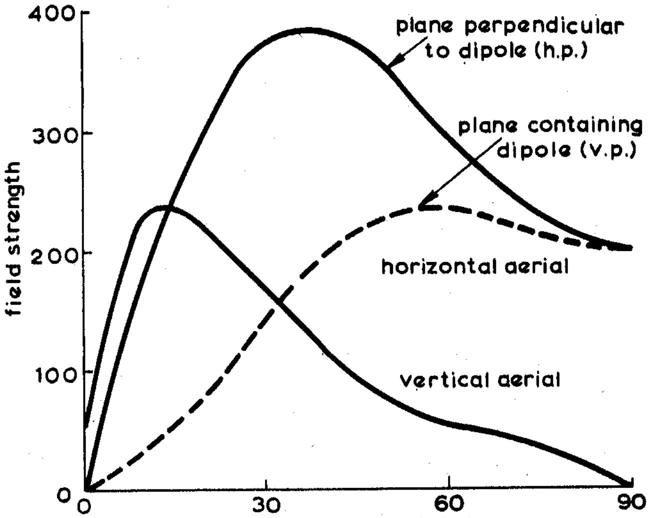

Fig. 1 - Vertical Radiation patterns

Vertical Aerial : $0{\cdot}5\lambda$ mast radiator
Horizontal Aerial : $0{\cdot}5\lambda$ dipole $0{\cdot}4\lambda$ above ground

Ground conductivity : 5×10^{-3} mhos/m   Frequency : 1 MHz

The vertical scale shows the product Ed (in volts) of the field strength E and the distance d, when 1 kW is radiated.

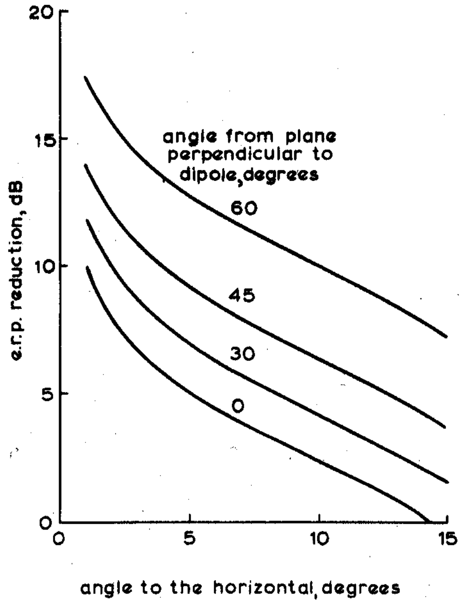

Fig. 2 - Reduction of effective radiated power when horizontal aerial replaces vertical aerial

Vertical aerial : 0·5λ mast radiator
Horizontal aerial : 0·5λ dipole 0·4λ above ground

Fig. 2 shows the reduction of effective radiated power (e.r.p.) which would occur at low angles if the vertical aerial were replaced by the horizontal aerial, the transmitter being unchanged. The curves of Fig. 2 are confined to the arcs within which the horizontally polarized component predominates. Although these e.r.p. reductions may be regarded as typical, they will be modified if the horizontal aerial contains more than one dipole.

3. POLARIZATION COUPLING LOSS

In general, a wave incident upon the ionosphere excites both the ordinary and extraordinary waves. If one of these waves is considered, the power which it contains is less than the power contained in the incident wave; this reduction of power is called the 'polarization coupling loss' for that wave. It has been shown[1] that the polarization coupling loss which occurs when a plane-polarized wave radiated from a vertical aerial enters the ionosphere is given by

$$F_v = \frac{\cos^2\psi + M^2 \sin^2 \psi}{1 + M^2} \qquad (1)$$

where M is the axial ratio of the polarization ellipse of the wave excited in the ionosphere (ordinary or extraordinary) and ψ is the angle by which the ellipse is tilted from the vertical plane. M and ψ depend on the magnetic dip angle, direction of propagation and frequency; formulae for calculating M and ψ for the ordinary wave are given in Reference 1.

If a horizontally-polarized wave is radiated instead, the expression for the polarization coupling loss becomes

$$F_H = \frac{\sin^2\psi + M^2 \cos^2 \psi}{1 + M^2} \qquad (2)$$

The polarization coupling loss therefore changes by a factor

$$\frac{F_H}{F_v} = \frac{\sin^2\psi + M^2 \cos^2\psi}{\cos^2\psi + M^2 \sin^2\psi} \qquad (3)$$

This change may be regarded as an increase in the coupling loss of 10 $\log_{10}(F_v/F_H)$ decibels.

Fig. 3 shows how the use of horizontal polarization affects the polarization coupling loss for the ordinary wave. The loss is increased at high latitudes because the predominantly vertically-polarized ordinary wave is excited less efficiently, but in tropical latitudes it is reduced, especially on east-west paths, where the ordinary-wave polarization is almost horizontal.

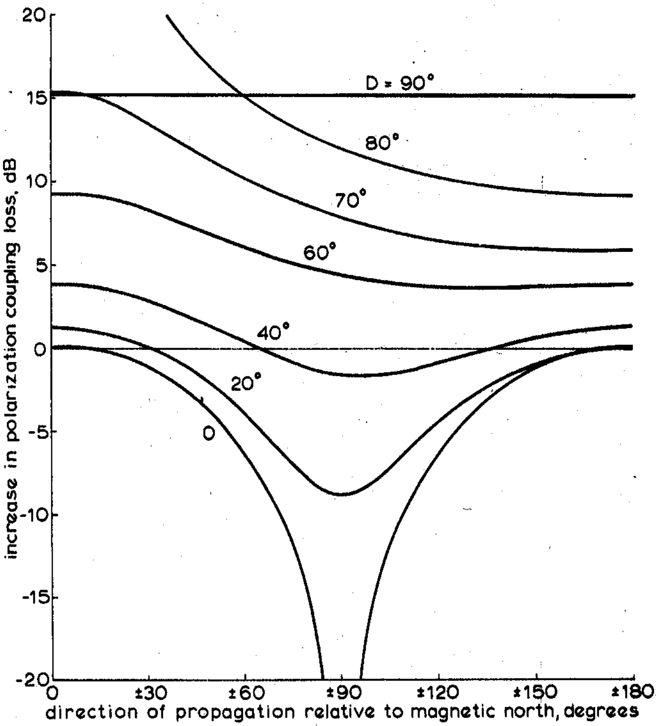

Fig. 3 - Increase in polarization coupling loss if horizontal polarization is radiated

D = Dip latitude. Curves are for the Northern Hemisphere but also apply in the Southern if direction of propagation is measured relative to magnetic South

The curves of Fig. 3 were calculated for an angle of incidence at the ionosphere of 80°; this corresponds to an angle of elevation at the ground of about 5° and a hop-length (assuming E-layer reflection) of about 1500 km. The wave frequency was assumed to be equal to the gyromagnetic frequency (1·2 to 1·4 MHz in Europe). The curves may be used with little error for ground elevation angles up to 15°, and for all frequencies in the m.f. band throughout the world.

4. FIELD-STRENGTH REDUCTION

At m.f. the extraordinary wave is greatly attenuated and only the ordinary wave need be considered. Field strength reductions at low angles, resulting from the use of horizontal aerials, may therefore be estimated by adding polarization coupling loss increases for the ordinary wave derived from Fig. 3 to e.r.p. reductions similar to those of Fig. 2, provided the radiation from the aerial is predominantly horizontally-polarized. If the vertical component predominates there will be little change in the polarization coupling loss but the e.r.p. reduction must still be considered.

Thus waves propagating at 5° to the horizontal from the aerials discussed here would be reduced in strength by at least 9 dB at 60° dip latitude, even in the plane in which the horizontal aerial radiates most strongly; 60° from this plane the reduction would be at least 17 dB. Nearer the dipole axis the radiation contains a significant vertical component, but here the e.r.p. is so low that a substantial reduction of field strength remains. This example shows how the use of a horizontal aerial may reduce the field strength at distances greater than 1000 km in European and other temperate latitudes. In some directions the reduction may exceed 20 dB.

In tropical latitudes a distinction must be made between north-south and east-west paths. On north-south paths the change in polarization coupling loss is small and only the e.r.p. reduction remains. The reduction in field strength is therefore smaller than that experienced in temperate latitudes. On east-west paths, radiation from vertical aerials is subject to very high polarization coupling losses. Although the coupling losses at the transmitting end of the path are greatly reduced if a horizontal aerial is used, the e.r.p. reduction remains and the field strength will be similar to that on north-south paths. Because of the e.r.p. reduction, the distant field strength is unlikely to exceed that due to vertical aerials in temperate latitudes, whatever the direction of propagation.

5. CONCLUSIONS

If a vertical aerial is replaced by a horizontal aerial of similar size radiating the same power, the field strength observed at distances greater than 1000 km in European and other temperate latitudes will be reduced by amounts which may be as much as 20 dB. The use of horizontal aerials instead of vertical aerials for m.f. broadcasting will therefore cause less interference at long distances in these latitudes.

In tropical latitudes polarization coupling losses are reduced if waves are radiated from horizontal aerials. Transmissions from horizontal aerials will therefore cause more interference, but the interference level is unlikely to exceed that experienced in temperate latitudes when conventional vertical aerials are used.

6. REFERENCE

1. PHILLIPS, G.J. *and* KNIGHT, P. 1964. Effects of polarisation on a medium-frequency sky-wave service, including the case of multi hop paths. *Proc. Inst. elec. Engrs,* 1965, **112**, pp. 31–39.

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